ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

Investigation of Low velocity Impact Properties of Kevlar Fiber Reinforced Polymer Matrix Composites

[1] S. Channabasavaraju, [2] Dr. H. K. Shivanand, [3] Santhosh Kumar. S
[1] *Research Scholar, UVCE, Bangalore University, Bangalore-01*
[2] *Associate Professor, UVCE, Bangalore-01*
[3] *Assistant Professor, RNSIT, Bangalore*

Abstract

The work presented in this project investigates the experimental study of low velocity impact properties of Kevlar fiber reinforced polymer matrix composite materials with respect to different thickness. Behaviour of Kevlar fibre-reinforced composite materials is studied. The test specimens are fabricated by simple hand lay-up technique and prepared according to ASTM standards. Visual examination of the impacted samples reveals that the damage in the fibres was developed around the point of impact, which results in considerable strength loss.

1. Introduction

Today the threat of impact damage and the problems associated with the holes are the limiting design criteria for composite material especially in airframe structures. It is considered potentially dangerous mainly because the damage might be left undetected. In many situations, the level of impact at which visible damage is formed is much higher than the level at which substantial loss of residual properties occurs.

At the normally very conservative design strain level of 0.4 percent, the problem is not alarming, but not being able to use the new high strain fibers more efficiently is a serious limitation. Most of the test methods used today are not really pure material tests. The influence of structural response of the test specimen often overshadows the behavior of the material. In the case of impact testing, the extremely complex stress state, coupled with the dynamic phenomena, makes comparisons between different test setups and materials very difficult, if not impossible.

The objective during initial investigation was to gain a better understanding of the fundamental low-velocity impact phenomena. The primary focus was on test method development, as well as material and damage characterization. Since the field of impact on composite structures is still in its infancy, no commonly accepted analytical methods or test procedures are available.

2. Literature Review

Rapid growth in the use of fiber-reinforced, polymer matrix composites has taken place over the past fifteen years. The earliest applications for these materials have been primarily in the military and defense industries (e.g. primary and secondary structures in military aircraft). More recently, the civilian industries have expressed interest in these materials. These industries are showing interest in these materials primarily because of their combined strength and corrosion/chemical resistance.

The combination of properties allows for longer life and lower maintenance costs over the lifetime of a structure when compared to conventional structural materials. A considerable amount of research has been done on the impact resistance of laminated composites. Experimental and analytical studies have confirmed that static indentation tests provide useful information about the failure mechanisms and failure loads for large mass impactors at low velocities [1-4].

As a consequence, current understanding of the dynamic damage growth mechanisms due to the impact is still limited although a vast amount of analytical data and some studies on the impact damage of laminates under low-velocity impact can be found in the literature. Choi et el. [5,6] analyzed the impact damage mechanism and mechanics of glass/epoxy laminated composites, in which they designed and built an impact tester, controlling impact loading by choosing different nose shapes of the impactor.

An analytical model based on the a plane strain assumption was proposed for predicting the occurrence of the impact damage due to the line-loading impact and the subsequent damage resulting from the initial damage. Hosur et al. [6] examined the impact-induced damage in CFRP laminates through ultrasonic images. Ultrasonic C-scan using the pulse echo immersion method was utilized to read out the delamination area caused by the low velocity impact on composite laminates. Luo et al. [7] developed an integrated procedure for modeling and testing glass/epoxy composite plates.

3. Methodology

The Test laminates of 300mm X 300 mm were initially fabricated to prepare impact test specimens by vacuum bag moulding method followed by Room temperature. The resin and the hardener of required quantities are taken in a previously weighed empty bowl. They are mixed properly in the bowl using a paintbrush. The laminates are prepared by hand lay up process later vacuum bag is applied on it to get exact thickness and to distribute matrix uniformly. Finally the specimen was allowed to cure for 48hrs in RT after that specimens are kept for post curing. Post curing is a technique used to take to completion in the process of curing as well as to ensure the enhancement of the service temperature limits. The post curing, in essence, increases the glass transition temperature (Tg) of the cured composite laminate.

Specimen Designation	**Panel Size (Mm)**	**Specimens Used**
Panel C – Kevlar Fiber	150 X 150 X T	12 Nos.

Where t= Thickness (2mm, 3mm)
Fig Composite Panels Specifications

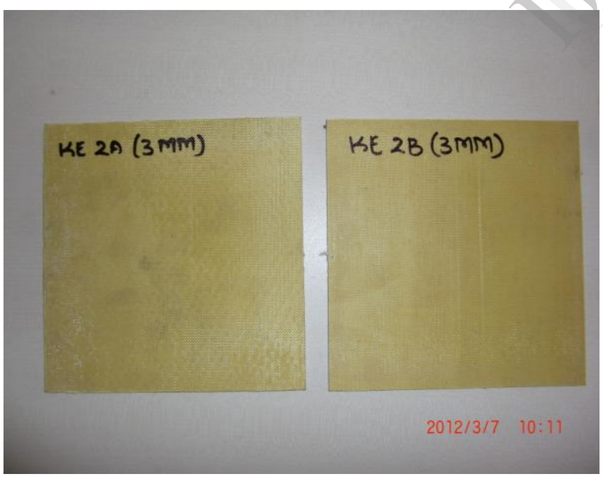

Fig 5.2: Machined Impact Test Specimens as per ASTM (D 3763) Standards

4. Results and Discussions

Specimen	Mass (Kg)	Height (meter)	Impact energy (J)	P_{ab} (N)	E_{ab} (J)	Remarks
K2A		0.4	9.81	1990	7.65	No Crack
K2B	2.5	0.7	17.17	2100	15.53	Partial Penetration
K2C		1.0	24.52	2850	23.15	Full Penetration
K2D		0.4	19.76	2450	15.10	No Crack
K2E	5.0	0.7	34.58	2650	28.28	Partial Penetration
K2F		1.0	50.19	3550	43.25	Full Penetration

Fig Kevlar Fiber Bi-woven / Epoxy resin composite (2 mm thick)

Specimen	Mass (Kg)	Height (meter)	Impact energy (J)	P_{ab} (N)	E_{ab} (J)	Remarks
K1A		0.4	9.81	1220	7.95	No Crack
K1B	2.5	0.7	17.17	1700	13.70	Partial Penetration
K1C		1.0	24.52	2420	24.30	Full Penetration
K1D		0.4	19.76	2550	15.76	No Crack
K1E	5.0	0.7	34.58	3610	34.00	Partial Penetration
K1F		1.0	50.19	3800	43.98	Full Penetration

Kevlar Fiber Bi-woven / Epoxy resin composite (3 mm thick)

Visual examination of the impacted samples reveals that the damage in the fibres was developed around the point of impact, which results in considerable strength loss. This is observed as steep decrease in impact force in the curves. Some curves show a zigzag (several humps) pattern suggesting that there exists a multiple step failure mode during the impact.

Certain curves show bilinear behaviour (valleys and humps) following an initial linear response. The valleys are due to reduction of the stiffness of the core caused by the onset of crushing. The interface of the core and the skin resist further crushing, which is manifested as humps. Further valleys are due to the interface failure caused by debonding. This behaviour, which continues throughout the second region, probably means that the local rigidity, rather than the overall structural rigidity, is involved in the impact phenomenon.

Contrastingly, the present investigation did not reveal this type of damage, which evidences that a strong adhesive bonding exists between the layers of the composite panel. Damage of the backsheet under the impactor is either visible or hidden. The impact force can produce high through-thickness shear in the skin, which causes local delamination of the skin. These delaminations can grow during the impact process, and if spring-back occurs, part of the skin below the delamination may remain attached to the core as the remainder of the skin recovers, opening the delamination further.

5. Conclusions

- The Impact response of laminated composite specimens with varying impact energy has been investigated.
- These tests have shown that the dynamic response of these systems depends on the elastic properties such as strength, modulus of the constituent materials.
- For a given impact energy, the absorbed energy tend to increase in case of 3mm thickness specimens as compared to 2mm thickness specimen for the same height of fall.
- Finally, we conclude that these investigations on fiber reinforced composite specimen can be successfully modeled using mechanical properties determined at different high strain rates and yields an important design parameter for structures subjected to impact loading.

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